2.3 STRESS CONDITIONS IN SOIL:

Total stress (or) Unit pressure (σ):

Total load per unit area. This pressure may be due to

1) Self weight of soil (saturated weight, if soil is saturated).
2) Over-burden on the soil.

Consists of two component:

1) **Inter granular pressure (or) effective pressure (or) effective stress (σ'):**

- It is the pressure transmitted from particle through their point of contact through their soil mass abovethe plane.
- It is effective in decreasing the voids ratio of the soil mass and in mobilizing its shear strength.

2) **Neutral pressure (or) pore water pressure (u) :**

- It is the pressure transmitted through the pore fluid.
- It is equal to water load per unit area above the plane.
- It does not have any influence (measurable) on the voids ratio or any other mechanical property ofthe soil such as shearing resistance.

$$\sigma = \sigma' + u$$

Total vertical pressure = Effective pressure + pore pressure

At any plane,

Pore pressure, u = piezometric head (h_w) x unit weight of water (γ_w)

$$u = h_w \gamma_w$$

To find the value of effective pressure we shall consider different conditions of soil water system.

1) Submerged soil mass:
2) Soil mass with surcharge:
3) Partially saturated soil:
4) Saturated soil with capillary fringe**:**

1) Submerged soil mass:

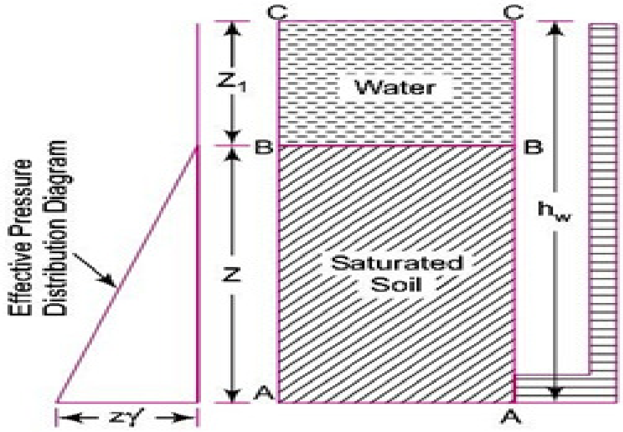


Fig 2.5 Submerged soil mass

Fig2.5, shows saturated soil mass of depth z, submerged under water of height z_1 above its top level. If a piezometric tube is inserted at level AA, water will rise in it upto level CC.

Now, total pressure at AA isgiven by,

$$\sigma = Z\gamma_{sat} + Z_1\gamma_w$$

Pore pressure, $u = h_{w}\,.\,\gamma_w$

$\sigma' = \sigma - u$

$= Z\,\gamma_{sat} + Z_1\,\gamma_w - h_{w}\,.\,\gamma_w$

$= Z\,\gamma_{sat} + Z_1\,\gamma_w - (Z+Z_1)$

$\gamma_w\sigma' = Z\,(\gamma_{sat} - \gamma_w)$

$$\sigma' = Z\gamma'$$

@B-B

$\sigma = \gamma_{W}.Z_2$

$U = \gamma_{W}.h_W$

$\sigma' = \sigma - U$

$=0$

@C-C

The total, effective and pore water pressure are zero

2) Soil mass with surcharge:

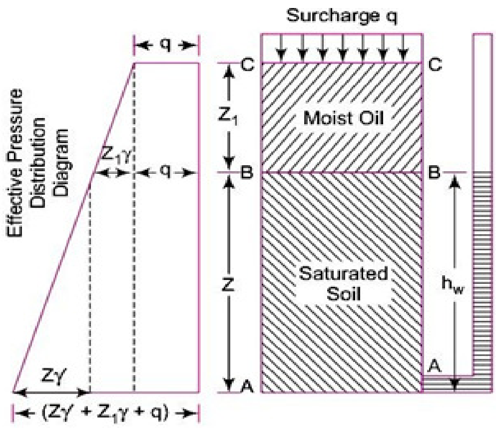


Fig 2.6 soil mass with surcharge

Let us now consider a moist soil mass of height Z_1 above the saturated mass of height Z. Soil mass supports a surcharge pressure of intensity 'q' per unit area.

At level AA, the pressure is,

$\sigma = q + Z_1\,\gamma + Z\,\gamma_{sat}$

$u = h_w\,.\,\gamma_w$

$= Z\,\gamma_w$

$\sigma' = \sigma - u$

$= q + Z_1\,\gamma + Z\,\gamma_{sat} - Z\,\gamma_w$

$\sigma' = q + Z_1\,\gamma + Z\,\gamma'$

At the plane BB,

$\sigma = q + Z_1\,\gamma$

$u = h_w\,.\,\gamma_w$

$= 0$

At the plane C-C

$\sigma = q$

$U=0$

$\sigma' = \sigma - u$

$=q$

3) **Partially saturated soil:**

In a partially saturated soil, a part of void space is occupied by air. Hence, in addition to pore waterpressure (u_w) pore air pressure (u_a) will also to there.

Bishop (1959) based on his intuition gave the following expression for the effective stress.

$$\sigma' = \sigma - u_a + x\,(u_a - u_w)$$

where, u_a = pore air pressure

u_w = pore water pressure

x = factor of unit c/s area

Occupied by water $x = \frac{A_w}{A}$

Aw = Area of water A = Area of c/s of soil

If (S >= 90%) near unity it is recommended to

take 'x' as unity (ie., 1).$\sigma' = \sigma - u_w$

$$\sigma' = \sigma - u$$

4) **Saturated soil with capillary fringe:**

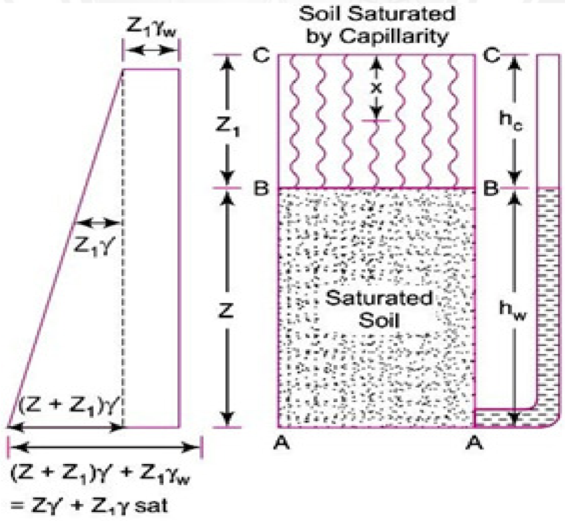


Fig 2.7 Saturated soil with capillary fringe

Fig 2.7 shows a saturated soil mass of height Z above this, there is a soil mass of height Z_1 saturated by capillary water. If we insert a piezometric tube at AA, water will rise to a height corresponding to the free water level BB

Hence at the level AA,

$$\sigma = Z\gamma_{sat} + Z_1\gamma_{sat}$$

$$u = Z\gamma_w$$

$$\sigma' = \sigma - u$$

$$= Z\gamma_{sat} + Z_1\gamma_{sat} - Z\gamma_w$$

$$\sigma' = Z_1\gamma' + Z_1\gamma_{sat}$$

Hence at the level BB,

$$\sigma' = Z_1\gamma' + Z_1\gamma_w = Z_1\gamma_{sat}$$

At the level CC

$\sigma^1=0$

$U=h_w\gamma_w=(-z_1)xh_w$

$\sigma = \sigma^1 - U$

$=0-(-h_w z_1)$

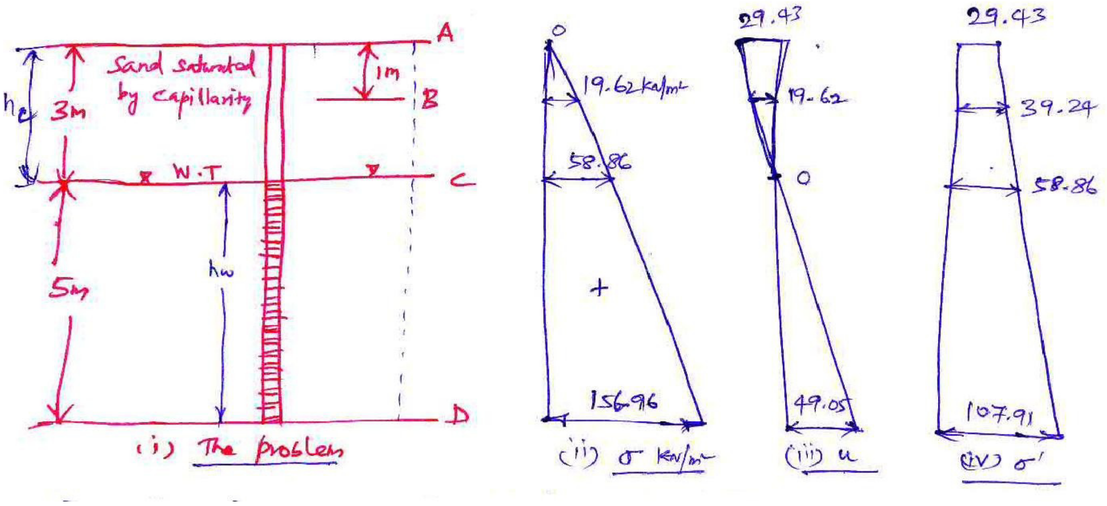
$= h_w z_1$

Problem

1) The water table in a deposit of sand 8m thick, is at a depth of 3m below the surface. Above the W.T. the sand is saturated with capillary water. The bulk density of sand is 19.62 kN/m^3 . Calculate the effective pressure at 1m, 3m and 8m below the surface. Hence plot the variation of total,neutral pressure and effective pressure over the depth of 8m.

a) **Stresses at D, 8m below ground:**

If we insert a piezometric tube at D, water will be rise through a height h_w = 5m in it.



$\sigma = (3+5)\ \gamma_{sat} = 8 \text{ x } 19.62 = \underline{156.96}$ kN/m^2

$u = h_w.\gamma_w = 5 \text{ x } 9.81 = \underline{49.05}$ kN/m^2

$\sigma' = \sigma - u = 156.96 - 49.05 = \underline{107.91}$ kN/m^2

Alternatively, $\sigma' = 5\,\gamma' + 3\,\gamma_{sat}$

$= 5 \times 9.81 + 3 \times 19.62 = \underline{107.91}$ kN/m^2

b) Stresses at C, 3m below G.L.:

$\sigma = 3\,\gamma_{sat} = 3 \times 19.62$

$= \underline{58.86}$ kN/m^2

$u = 0$ (zero)

$\sigma' = 58.86$ kN/m^2

Alternatively, $\sigma' = h \times \gamma_{sat} = 3 \times 19.62$

$= \underline{58.86}$ kN/m^2(or) $\sigma' = 3$

$\times\, \gamma' + h_c.\gamma_w$

$= 3\,(19.62 - 9.81) + 3 \times 9.81$

$= \underline{58.86}$ kN/m^2

c) Stresses at B, 1m below G.L:

$\sigma = 1\,\gamma_{sat} = 1 \times 19.62 = \underline{19.62}$ kN/m^2

$u = -2\,\gamma_w = -2 \times 9.81 = \underline{-19.62}$ kN/m^2

(ie., pressure due to weight of water hanging below that level)

$\sigma' = (\sigma - u)$

$= 19.62 - (-19.62)$

$= \underline{39.24}$ kN/m^2

d) Stresses at A, at Ground Level.:

$\sigma = 0$

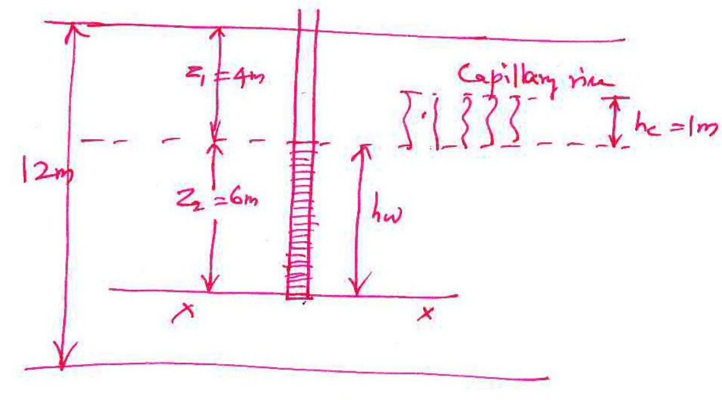
$u = -\,h_c.\gamma_w = -3\,(9.81)$

$= \underline{-29.43}$ kN/m^2

$\sigma' = 0 - (-\,29.43)$

$\sigma' = \underline{29.43}$ kN/m^2

2) The water table in a certain area is at a depth of 4m below the ground surface, to a depth of 12m, the soil consists of very fine sand having an average voids ratio of 0.7. Above the water table the sand has an average degree of saturation of 50%. Calculate the effective pressure on a horizontal plane at a depth 10m below the ground surface. What will be the increase in the effective pressure if the soil gets saturated by capillary upto a height of 1m above the W.T.? (Assume G = 2.6).



Solution:

Height of sand layer above the w.t = Z_1 = 4m

Height of saturated layer = 12 - 4 =8m

Depth of point x, where pressure is to be computed = 10m

Height of saturated layer above x = Z_2 =10 – 4 = 6m

$$\gamma_d = \frac{G.\gamma_w}{1+e}$$

$$= \frac{2.65x9.81}{1+0.7}$$

$$= 15.29KN/m^3$$

i) For sand above water table,

$$\gamma_1 = \frac{(G+eS)\gamma_w}{1+e}$$

$$\gamma_2 = \frac{(G+eS)\gamma_w}{1+e}$$

$$e = \frac{wG}{S}$$

$$w = \frac{eS}{G}$$

$$w = \frac{0.7x0.5}{2.65} = 0.132$$

$\gamma_1 = \gamma_d$ (1 + w) = 15.29 x (1 + 0.132) = <u>17.31</u> kN/m^3

ii) For saturated sand below water table, w_{sat}

$$w_{sat} = \frac{eS}{G}$$

$$w = \frac{0.7x1}{2.65} = 0.264$$

$\gamma_2 = \gamma_d$ (1 + w_{sat}) = 15.29 x 1.264 = 19.33 kN/m^3

γ_2' = 19.33 – 9.81 = <u>9.52</u> kN/m^3

($\gamma' = \gamma_{ref} = \gamma_{sat} - \gamma_w$)

Effective pressure at x,

$\sigma = Z_1 \gamma_1 + Z_2 \gamma_2'$ = (4 x 17.31) + (6 x 19.33)

σ = <u>185.222</u> kN/m^2

u = $h_w.\gamma_w$ = 6 x 9.81

= <u>58.86</u> kN/m^2

$\sigma' = \sigma - u$ = 185.22 – 58.86

= <u>126.36</u> kN/m^2

Effective stress at x after capillary rise,

$\sigma' = 3\ \gamma_1 + (6 + 1)\ \gamma_2' + h_c.\gamma_w$

= (3 x 17.31) + (7 x 9.52) + (1 x 9.81)

=<u>128.38</u> kN/m^2

Increase in pressure = 128.38 – 126.36

= <u>2.02</u> kN/m^2

(or) $\sigma = Z_1 \gamma_1 + Z_2 \gamma_2' + h_c.\gamma_w$

= 3 x 17.31 + 7 x 19.33 + 1 x 9.81 = <u>197.05</u> kN/m^2

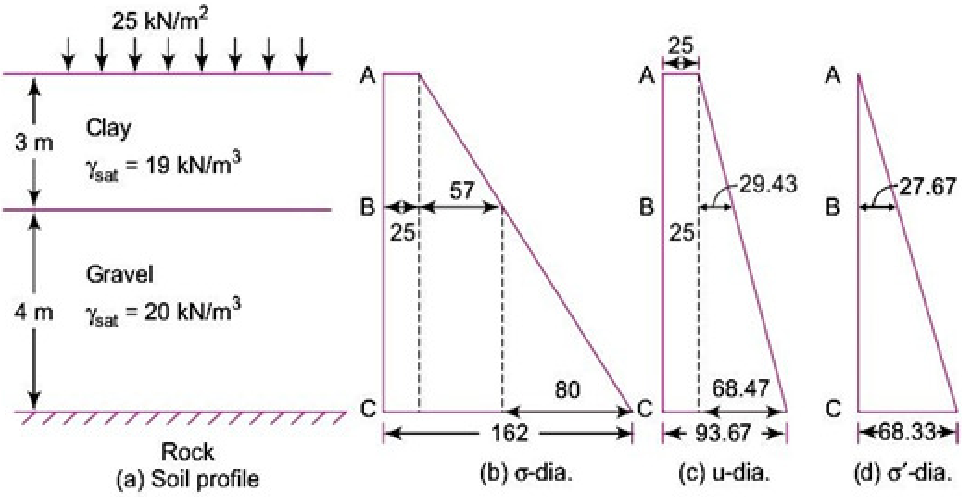
U = 7 x 9.81 = <u>68.67</u> kN/m^2

$\sigma' = \sigma - u$

=197.05 – 68.67

=<u>128.38</u> kN/m^2

3) At a construction site ,a 3m thick clay layer is followed by a 4m thick gravel layer which is resting on impervious rock. A load of 25kN/m^2 is applied suddenly at the surface. The saturated unit weight of the soils is 19kN/m^3 and 20 kN/m^3 for the clay and gravel layers, respectively. The water table is at the surface. Draw diagrams showing variation with depth of total, neutral and effective stress in the layers.



At A-A

σ = 25 KN/m^2

U=25 KN/m^2 (Since load is applied suddenly the entire load is taken by pore water)

σ′ = σ – u

=25-25

=0 KN/m^2

At B-B

σ = 25+3x19=82 KN/m^2

U=25+9.81x3

=54.43 KN/m^2 (Since load is applied suddenly the entire load is taken by pore water)

σ′ = σ – u

=82-54.43

=27.57 KN/m^2

At C-C

σ = 25+3x19+4x20=162 KN/m^2

U=25+9.81x3+9.81x7 =93.67 KN/m^2 (Since load is applied suddenly the entire load is taken by pore water)

$\sigma' = \sigma - u$

=162-93.67=68.33KN/m^2